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Hot DAVs: a probable new class of pulsating white dwarf stars

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ABSTRACT

We have discovered a pulsating DA white dwarf at the lower end of the temperature range 45 000–30 000 K where a few helium atmosphere white dwarfs are known. There are now three such pulsators known, suggesting that a new class of theoretically predicted pulsating white dwarf stars exists. We name them the hot DAV stars. From high-speed photometric observations with the ULTRACAM photometer on the 4.2-m William Herschel Telescope, we show that the hydrogen atmosphere white dwarf star WD1017−138 pulsates in at least one mode with a frequency of 1.62 mHz (a period of 624 s). The amplitude of that mode was near 1 mmag at a 10σ confidence level on one night of observation and an 8.4σ confidence level on a second night. The combined data have a confidence level of 11.8σ. This supports the two other detections of hot DAV stars previously reported. From three Very Large Telescope Ultraviolet and Visual Echelle Spectrograph spectra we confirm also that WD1017−138 is a hydrogen atmosphere white dwarf with no trace of helium or metals with $T_{\rm eff} = 32\,600$ K, $\log g = 7.8$ (cgs) and $M = 0.55\ {\rm M}_{\odot}$. The existence of pulsations in these DA white dwarfs at the cool edge of the 45 000–30 000 K temperature range supports the thin hydrogen layer model for the deficit of helium atmosphere white dwarfs in this range. DA white dwarfs with thick hydrogen layers do not have the superadiabatic, chemically inhomogeneous (μ-gradient) zone that drives pulsation in this temperature range. The potential for higher amplitude hot DAV stars exists; their discovery would open the possibility of a direct test of the explanation for the deficit of helium atmosphere white dwarfs at these temperatures by asteroseismic probing of the atmospheric layers of the hot DAV stars. A search for pulsation in a further 22 candidates with ULTRACAM on the European Southern Observatory New Technology Telescope gave null results for pulsation at precisions in the range 0.5–3 mmag, suggesting that the pulsation amplitudes in such stars are relatively low, hence near the detection limit with the ground-based telescopes used in the survey.

Key words: stars: individual: WD1017−138 – stars: oscillations – white dwarfs.

1 INTRODUCTION

Almost all stars with masses less than 8 ${\rm M}_{\odot}$ end their lives as white dwarfs, the second most common stars in the Galaxy after main-sequence red dwarfs. Late in the life of a red giant star, its pre-white dwarf core becomes visible as the stellar envelope is expelled – taking with it almost all of the hydrogen and most of the helium in the star, and leaving behind a high-density carbon–oxygen core with small amounts of residual helium and hydrogen in the observable atmosphere. White dwarfs have no nuclear energy sources – they shine only by radiating their remaining heat, which is primarily in their atomic nuclei.

Since white dwarfs are very compact and most of them are faint, they are difficult to detect. Indeed, the number of known white dwarfs was no more than several hundreds until the 1990s. Since then, this situation has changed dramatically by the systematic surveys providing massive data sets; see, e.g. Vennes et al. (2002), Homeier (2003), Eisenstein et al. (2006b) and Kleinman (2010). The Sloan Digital Sky Survey (SDSS) has particularly made an

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enormous contribution. The Fourth Data Release of the SDSS (Eisenstein et al. 2006b) increased the number of known white dwarfs to more than 9300, and the Seventh Data Release (Kleinman 2010) enlarged it to more than 25 000.

According to Eisenstein et al. (2006b), the vast majority of these stars, 86 per cent, are classified as DA white dwarfs, meaning that they have hydrogen atmospheres, by analogy with main-sequence A stars whose visible spectra are dominated by Balmer absorption lines of hydrogen. The SDSS DA white dwarfs are found across a wide range of surface temperatures, from $T_{\rm eff} = 100\,000$ K at the hot end down to a temperature near to that of the Sun of only $T_{\rm eff} = 6300$ K. Of the rest of the SDSS white dwarfs, 8 per cent are classified as DB white dwarfs, and a smaller fraction as DO white dwarfs, meaning that they have helium atmospheres, by analogy with the main-sequence O and B stars whose visible spectra show strong absorption lines of ionized and neutral helium, respectively.

Unlike the DA white dwarfs, DO stars are found only in the restricted temperature range $80\,000 \geq T_{\rm eff} \geq 45\,000$ K, and DB stars mainly in the range $30\,000 \geq T_{\rm eff} \geq 12\,000$ K. Prior to the SDSS, white dwarfs with no helium in their atmospheres populated the temperature range between 45 000 and 30 000 K that spans from the DO to DB stars. This temperature range became known for simplicity as the 'DB gap', meaning a range with almost no helium atmosphere white dwarfs (Liebert et al. 1986). This implies that, since all white dwarfs must evolve through this temperature range as they radiate away their residual heat, somehow helium atmosphere DO stars evolve into hydrogen atmosphere hot DA stars, and then back to helium atmosphere DB stars.

Recently, the SDSS has discovered 26 DB white dwarfs within the temperature range 45 000–30 000 K (Eisenstein et al. 2006a; Hügelmeyer & Dreizler 2009). This temperature range is thus strictly no longer a gap. However, it is found that there is still a deficit of a factor of 2.5 in the DA/non-DA ratio within this temperature range (Eisenstein et al. 2006a). This deficit of helium atmosphere white dwarfs in the 45 000–30 000 K range is not an observational selection effect. If the stars had helium in their atmospheres, it would be readily apparent in their visible spectra, as it is in those helium atmosphere white dwarfs that have now been found in this temperature range.

This deficit is qualitatively expected from the theoretical point of view. As time passes white dwarfs simply cool, yet remarkably, many of them change from pure helium atmospheres (DO stars) to pure hydrogen atmospheres (DA stars), and then back to pure helium atmospheres (DB stars). This is understood in terms of a model of a nearly pure helium atmosphere with a tiny amount of residual hydrogen. At temperatures where the atmosphere is convective, the hydrogen is mixed to such low abundance as to be invisible. But in the temperature range along the cooling sequence from 45 000 to 30 000 K, there is no convective driving from helium and the little remaining hydrogen floats to the surface, hiding the helium layer beneath it (Fontaine & Wesemael 1987; Shibahashi 2005). The stars that continue to show helium atmospheres in this temperature range are thus conjectured to have too little hydrogen to mask the helium, or even no hydrogen at all. The relative deficit of helium atmosphere white dwarfs in this temperature range leads us to consider the concept of a 'gap' still to be significant.

Shibahashi (2005, 2007) revisited the model of Fontaine & Wesemael (1987). He found at the cool edge of the 45 000–30 000 K temperature range that the atmosphere is superadiabatic and convectively stabilized by a chemical composition gradient with the lighter, cooler hydrogen floating on top of the heavier helium layer. Under this condition he found that the radiative heat exchange leads to an asymmetry in g-mode oscillatory motion such that the oscillating elements overshoot their equilibrium positions with increasing velocity. A linear local stability analysis based on the dispersion relation led him to predict that g-modes should be excited in DA stars at the cool edge of the DB gap, pulsating in higher degree (ℓ) modes, but with some $\ell < 3$ modes excited, so possibly observable.

Now three members of this predicted (Shibahashi 2005; Kurtz et al. 2008) new class of pulsating white dwarfs, which we name the hot DAV stars, are known. We present the discovery of one of these in this paper; its existence supports the reality of the previous two announced by Kurtz et al. (2008). There have been some studies that suggest thick hydrogen layers for all DA white dwarfs (Fontaine et al. 1994; Robinson et al. 1995; Kleinman et al. 1998). The existence of pulsations in the hot DAV stars at the cool edge of the 45 000–30 000 K temperature range proves that their atmospheric hydrogen layers are thin – ruling out thick hydrogen layer models for them and showing that convective mixing explains their chameleon-like changes from helium to hydrogen to helium atmospheres. Asteroseismology of other white dwarf stars has probed the thicknesses of their atmospheric layers (Fontaine & Brassard 2008; Winget & Kepler 2008); thus, our suggested new class of pulsating white dwarfs promises probes of the detailed physics of the hydrogen–helium atmospheric transition in degenerate stars.

Pulsating white dwarfs allow detailed asteroseismic study of their atmospheres and interiors, and thus may shed light on the nature of the deficit of helium atmosphere white dwarfs in the 45 000–30 000 K temperature range. There are three main recognized classes of pulsating white dwarfs: (1) the hydrogen atmosphere (DA) ZZ Cet stars with effective temperatures in the range 11 000–12 500 K; (2) the helium atmosphere (DB) V777 Her stars with effective temperatures in the range 21 800–27 800 K; and (3) the GW Vir stars with effective temperatures in the range 75 000–170 000 K. In addition, there is a remarkable new class of pulsating carbon atmosphere white dwarf stars, the DQV stars, with megagauss magnetic fields, of which there are now five known members (Dufour et al. 2008, 2009, 2011; Montgomery et al. 2008).

Asteroseismology has been highly successful for pulsating white dwarf stars. The most outstanding case is GW Vir itself, for which nearly 200 g-mode pulsation frequencies have been identified by Costa et al. (2008). Asteroseismic studies of white dwarfs lead to precise determinations of stellar masses and rotation rates, while constraining the masses of stratified atmospheric layers of hydrogen and helium, as well as the rates of evolutionary cooling. This ability to probe the stratified atmospheric layers of white dwarfs makes the discovery of new classes of pulsators exciting and important.

2 NEW EVIDENCE FOR THE CLASS OF HOT DAV STARS

We initiated a search for the predicted hot DAV stars (Kurtz et al. 2008) and discussed two pulsating stars with amplitude signal-to-noise ratios of 6σ and 4.4σ: SDSS J010415.99+144857.4 and SDSS J023520.02−093456.3, both DA stars at the lower end of the 45 000–30 000 K temperature range with effective temperatures around 30 000 K. Our detected signals for these stars have periods of 159 and 705 s, respectively, plausible periods for white dwarfs pulsating in g-modes. For example, the DBV V777 Her white dwarf pulsators have periods in the range of about 150–1100 s, and the much more common DAV ZZ Cet pulsating white dwarfs have periods in the range 100–1200 s (see e.g. Fontaine et al. 1994). Nevertheless, we did not announce a new class with these two

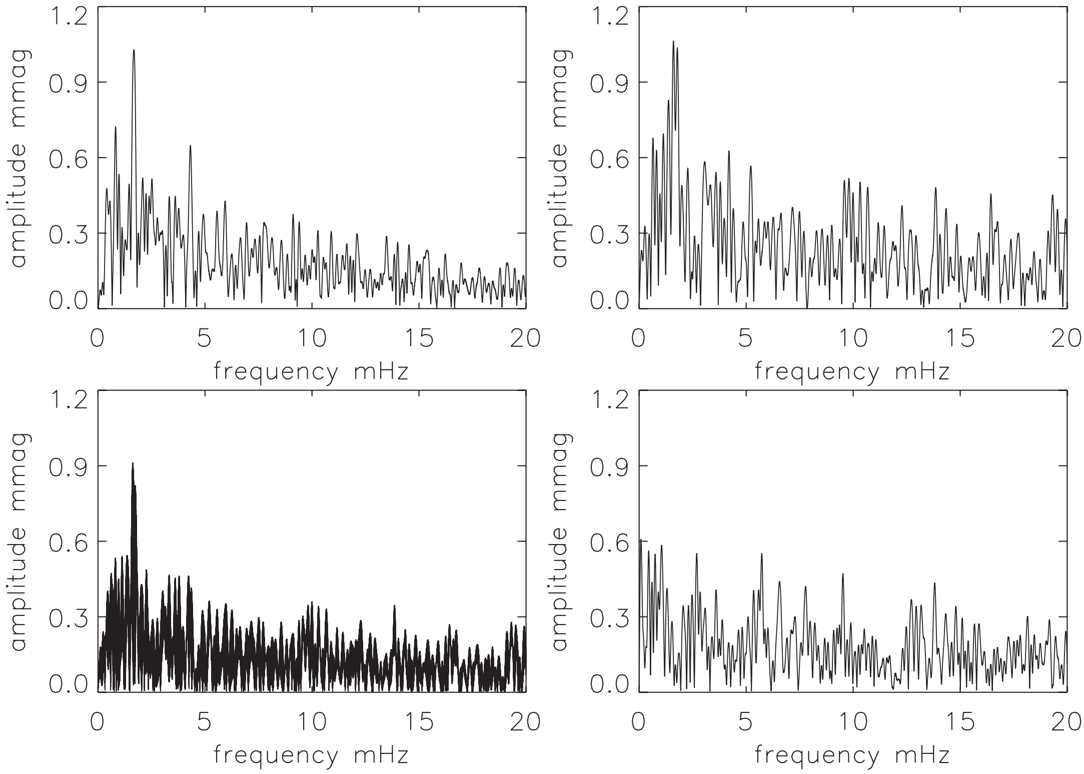

Figure 1. Discrete Fourier transform amplitude spectra of the light variations of WD1017−138. The upper-left panel shows the amplitude spectrum of the combined g' and r' light variations of WD1017−138 normalized to three comparison stars in a 2.3-h light curve obtained on JD 245 4832. The highest peak at 1.68 mHz has an amplitude signal-to-noise ratio of 10. The upper-right panel shows the amplitude spectrum of the 2.1-h follow-up light curve obtained four nights later where the highest peak is at the same frequency with an amplitude signal-to-noise ratio of 8.4. The lower-left panel shows the amplitude spectrum for the two nights combined, where the peak at 1.6247 mHz has an amplitude signal-to-noise ratio of 11.8σ, thus clearly proving the detection. The obvious aliases are the result of the 3-d gap between the two data sets. The bottom-right panel shows the amplitude spectrum of the light curve of one comparison star normalized to other two comparison stars, showing no variability, thus demonstrating that the signal in WD1017−138 is not instrumental in origin. The peak at 4.4 mHz in the upper-left panel is formally significant, but it was not confirmed in the upper-right panel on the second night; hence, we make no conclusion about it here.

detections, since we had not confirmed their pulsation signals on a second night.

Now we have a clear discovery with a 10σ signal with confirmation on a second night for the hot DAV white dwarf star WD1017−138 (B = 14.4). We observed WD1017−138 with the ULTRACAM photometer (Dhillon et al. 2007) on the 4.2-m William Herschel Telescope on two nights, 2008 December 31–2009 January 1 (JD 245 4832) and 2009 January 3 and 4 (JD 245 4835) for 2.3 and 2.1 h, respectively, in u', g' and r' filters, using 3-s integrations. Fig. 1 shows the amplitude spectra of the combined g' and r' light curves of WD1017−138 normalized to the mean of three comparison stars on both nights by subtraction of their magnitudes, the amplitude spectrum of the two nights combined and an amplitude spectrum of comparison star 1 normalized to the other two comparison stars. The highest peak in the amplitude spectrum on JD 245 4832 is f = 1.68 mHz with an amplitude determined from a least-squares fit of 0.90 ± 0.09 mmag, a 10σ detection. The highest peak on JD 245 4835 is at 1.60 mHz with a least-squares determined amplitude of 1.01 ± 0.12 mmag, an 8.4σ detection. Within the frequency resolution of 0.03 mHz (full width at half-maximum) for 2-h runs, these two nights show essentially the same peak. That the two light curves separated by 3 d can be phased with the same frequency is shown in the third panel of Fig. 1, where the highest peak is at f = 1.6247 ± 0.0001 mHz with an amplitude of 0.909 ± 0.077 mmag, giving an amplitude signal-to-noise ratio of 11.8σ.

This frequency, equivalent to a pulsation period of around 624 s, is typical for a pulsating white dwarf star. The false alarm probability of finding such a peak is $F = 1 - (1 - e^{-z})^{N_i}$, where z is the *power* signal-to-noise ratio, the square of the amplitude signal-to-noise ratio given above, and N_i is the number of independent frequencies searched (Horne & Baliunas 1986). Taking the frequency resolution to be the full width at half-maximum of the peaks in Fig. 1, which is about $1/4\Delta T$ for these data where ΔT is the time span of about 2 h, we searched 576 frequencies in the range 0–20 mHz. Taking $z = 100$ and noting that $e^{-z} \ll 1$, $F = N_i e^{-z} \sim 10^{-41}$, vanishingly small.

Could this short period be a rotational period in a spotted white dwarf? The break-up rotational period for a white dwarf is far shorter than this, so in principle, it could be. However, white dwarfs are generally known not to be spotted (Kawaler 2003; Wickramasinghe & Ferrario 2000), with the exception of WD1953−011, which has been suggested by Brinkworth et al. (2005) to have photometric rotational variations with a period of 1.4 d generated by a star spot or spots. Other rotation periods have been determined in some cases, primarily by asteroseismology. While a few are only slightly longer than the pulsation period of WD1017−138, the majority have rotation periods of hours to days, and longer. Even the rare strongly magnetic white dwarfs show rotation periods of days to over a century (Wickramasinghe & Ferrario 2000), hence are probably magnetically braked. Hence, we conclude that the signals seen in

WD1017−138 and the two other hot DAVs (J023520.02−093456.3, P = 705 s; J010415.99+144857.4, P = 159 s) discovered by Kurtz et al. (2008) are unlikely to be rotational in origin; they are pulsational.

3 NULL RESULTS FROM THE NTT

To follow up on our success in finding the predicted pulsations in WD1017−138, we were awarded five nights on the 3.5-m New Technology Telescope (NTT) of the European Southern Observatory (ESO) at La Silla, with the ULTRACAM photometer. We selected our target stars from Finley, Koester & Basri (1997) and from release 4 of the SDSS (Eisenstein et al. 2006b). The stars range in brightness from $B = 12.2$ to our self-imposed cut-off of $B = 17.5$. Table 1 lists the targets with their B, V or g' magnitudes and estimates of $T_{\rm eff}$, mostly from Finley et al. (1997). Observations were made using SDSS u', g' and r' filters with 1–10-s integrations, depending on the brightness of the star. In practice, the count rate in u' was very low, so only the g' and r' counts were added to produce pseudo-white light observations. Those counts were converted to differential magnitudes with respect to several comparison stars in the field of view for each star. Because most comparison stars are faint red dwarfs, there is often a colour difference between the white dwarf target star and the comparison stars. This leaves some residual amplitude in the amplitude spectrum at low frequency as a consequence of differential extinction. That can be seen in many of the amplitude spectra shown in Fig. 2. As the low-frequency limit to white dwarf pulsations is about 0.8 mHz ($P = 1200$ s), the upper limit to the pulsation listed in Table 1 is given as the amplitude of the highest noise peak in the frequency range 0.8–20 mHz. Inspection of the amplitude spectra in Fig. 2 shows that at higher frequencies the upper limit is often less than this value, i.e. the highest noise peak occurs at low frequency, so may still be a consequence of the differential extinction. In total, we obtained runs of duration 0.5–3.2 h for 22 stars.

Some of the 22 stars show formally significant peaks in the frequency range of pulsating white dwarf stars. Those are noted in the caption to Fig. 2. We conservatively do not accept amplitude signal-to-noise ratios of 3–4 as a detection of pulsation. There are possibilities for systematic errors to generate such signals. Our criterion for detection requires amplitude signal-to-noise ratios greater than 4σ *and* confirmation in independent observing runs on at least two nights. By this criterion the results for all 22 stars are null; there is no unambiguous pulsation signal in their amplitude spectra. This does not necessarily mean that they are not pulsating. For those with peaks in the 3–4σ range, follow-up observations are desirable and may be able to confirm pulsation.

We have found 5 stars in our previous study (Kurtz et al. 2008) and 21 stars in this study with no detectable pulsations at the level of 0.5–3 mmag, along with three stars in which pulsations were detected. We thus find 3 out of 29 stars tested, or 10 per cent, to have pulsations detectable above our noise limit. Given the low numbers tested so far, this is consistent with expectations of the ratio of thick hydrogen layer to thin hydrogen layer white dwarfs from the preponderance of DA to DB stars. We also note that for the DBV stars, Nitta et al. (2009) found 9 out of 29 stars with $T_{\rm eff} \sim 25\,000$ K tested to be pulsating, and 0 out of 4 DB stars with $T_{\rm eff} \sim 30\,000$ K (i.e. in the temperature range we were testing) to be pulsating with a noise limit of about 3 mmag – similar to ours. We surmise, as they did, that many of the non-detections may be

Table 1. NTT null results for 22 target stars. Effective temperature estimates have been rounded to the nearest 100 K primarily from Finley et al. (1997) and secondarily from Eisenstein et al. (2006b). The upper limit to any pulsation is given in mmag in the last column for pseudo-white light observations ($g' + r'$ filters) that are differential with respect to two or three comparison stars in the same field. Note that two entries are given for WD1844−223 for two separate nights.

Star name	mag	$T_{\rm eff}$ (K)	MJD$_{\rm start}$ 553 00.0+	MJD$_{\rm end}$ 553 00.0+	Δt (h)	npts	$A_{\rm max}$ (mmag)
WD1022−301	$V = 15.8$	35700	48.974 28	49.065 52	2.19	809	1.0
WD1056−384	$V = 14.1$	28200	47.945 36	48.027 55	1.97	2404	0.3
WD1125−025	$B = 15.3$	30800	45.971 85	46.054 06	1.97	3100	0.6
WD1438+013	$g' = 16.8$	31900	46.061 25	46.100 50	0.94	356	2.8
WD1511+009	$B = 15.6$	28100	47.036 95	47.111 47	1.79	1119	1.2
WD1532−006	$g' = 17.5$	29300	48.032 93	48.121 25	2.12	1326	2.5
WD1543−366	$B = 15.7$	45200	49.071 86	49.124 36	1.26	466	1.5
WD1609+044	$B = 15.2$	29500	47.115 76	47.195 21	1.91	1193	0.6
WD1615−154	$B = 12.2$	29600	46.114 36	46.197 42	1.99	3911	0.7
WD1620−391	$B = 10.9$	25300	48.129 27	48.192 14	1.51	2011	1.1
WD1844−223	$V = 14.0$	31500	48.197 73	48.329 98	3.17	4035	0.3
WD1844−223	$V = 14.0$	31500	50.127 73	50.200 21	1.74	2212	0.7
WD1845+019	$B = 12.7$	29500	46.200 30	46.266 23	1.58	990	0.7
WD1914+094	$B = 15.2$	33100	47.199 82	47.304 80	2.52	1576	1.1
WD2014−575	$B = 13.6$	26800	50.343 84	50.365 30	0.51	632	0.9
WD2020−425	$B = 14.7$	29500	46.282 43	46.344 92	1.50	1363	0.7
WD2043−635	$B = 15.4$	26000	50.368 94	50.438 54	1.67	1045	0.9
WD2151−307	$V = 14.4$	27700	47.309 44	47.350 92	1.00	1221	0.9
WD2241−325	$B = 16.4$	32500	46.349 57	46.432 88	2.00	1066	0.8
WD2307+009	$B = 16.9$	30900	48.381 10	48.434 43	1.28	801	2.0
WD2350−248	$B = 15.4$	29600	47.353 86	47.428 25	1.79	1117	0.9
J122722.84+021507.4	$g' = 17.3$	31800	46.950 93	47.032 93	1.97	727	2.0
J214001.04−075052.0	$g' = 16.0$	31900	48.334 34	48.378 93	1.07	670	0.4

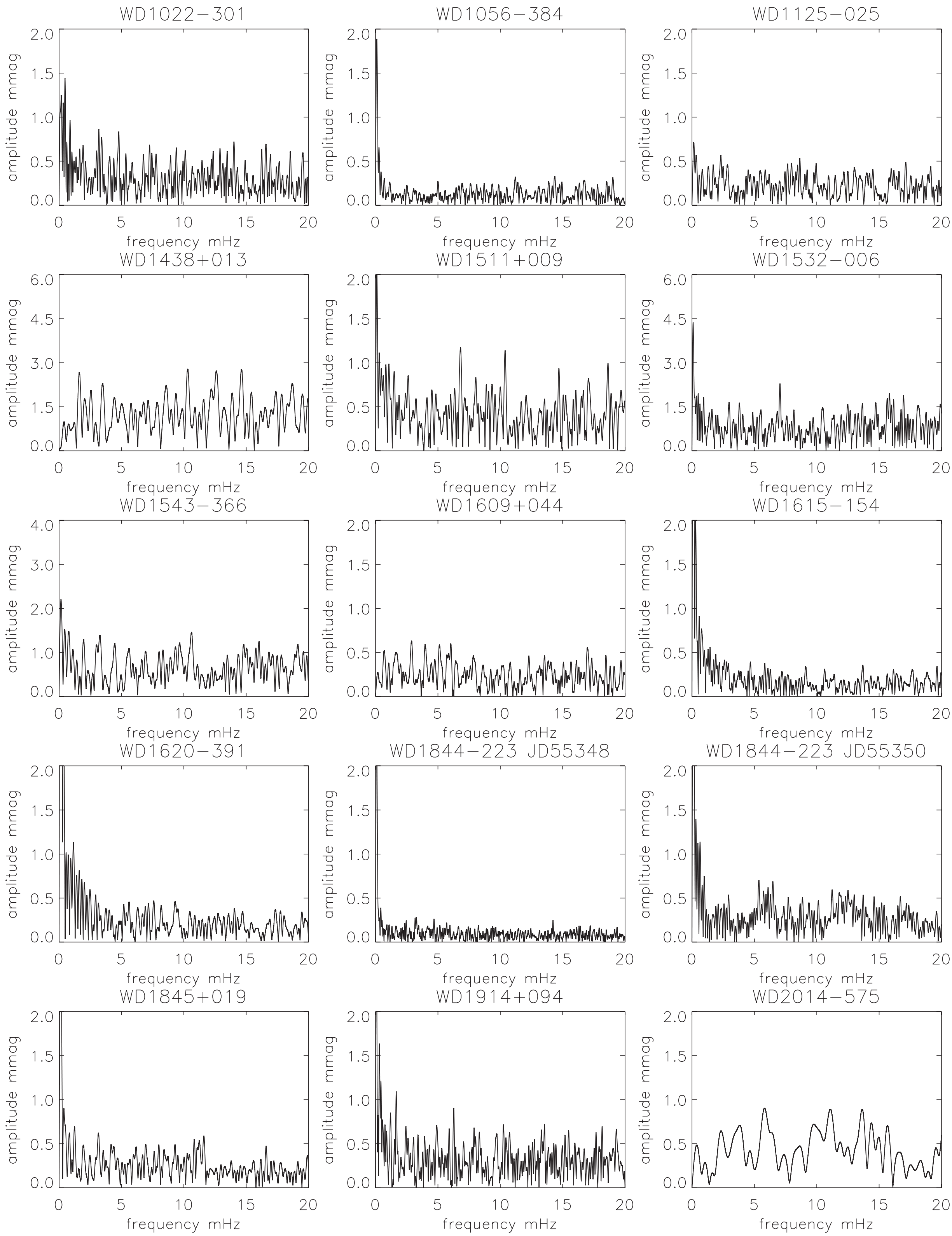

Figure 2. Null results for 22 white dwarf targets observed with ULTRACAM on the ESO NTT. Notes: from a least-squares fit the peak at 7.06 mHz for WD1532−006 has an amplitude signal-to-noise ratio of 3.3σ. For WD1511+009 the two peaks at 6.81 and 10.38 mHz have an amplitude signal-to-noise ratio of 3.5σ. For WD1532−009 the peak at 7.05 mHz has an amplitude signal-to-noise ratio of 3.3σ. For WD2043−635 the peak at 8.63 mHz has an amplitude signal-to-noise ratio of 4.1σ. The amplitude error has been calculated by a least-squares fit of a sinusoid to the data. That includes all variance in the data, and the noise is not white; there is some low-frequency increase in noise caused by the differential extinction between the programme stars and their comparisons stars. Typically, the least-squares determined noise level is about 1/4 the amplitude of the highest noise peaks. WD1844−223 was observed on two nights; hence, there are 23 panels in this plot and its continuation.

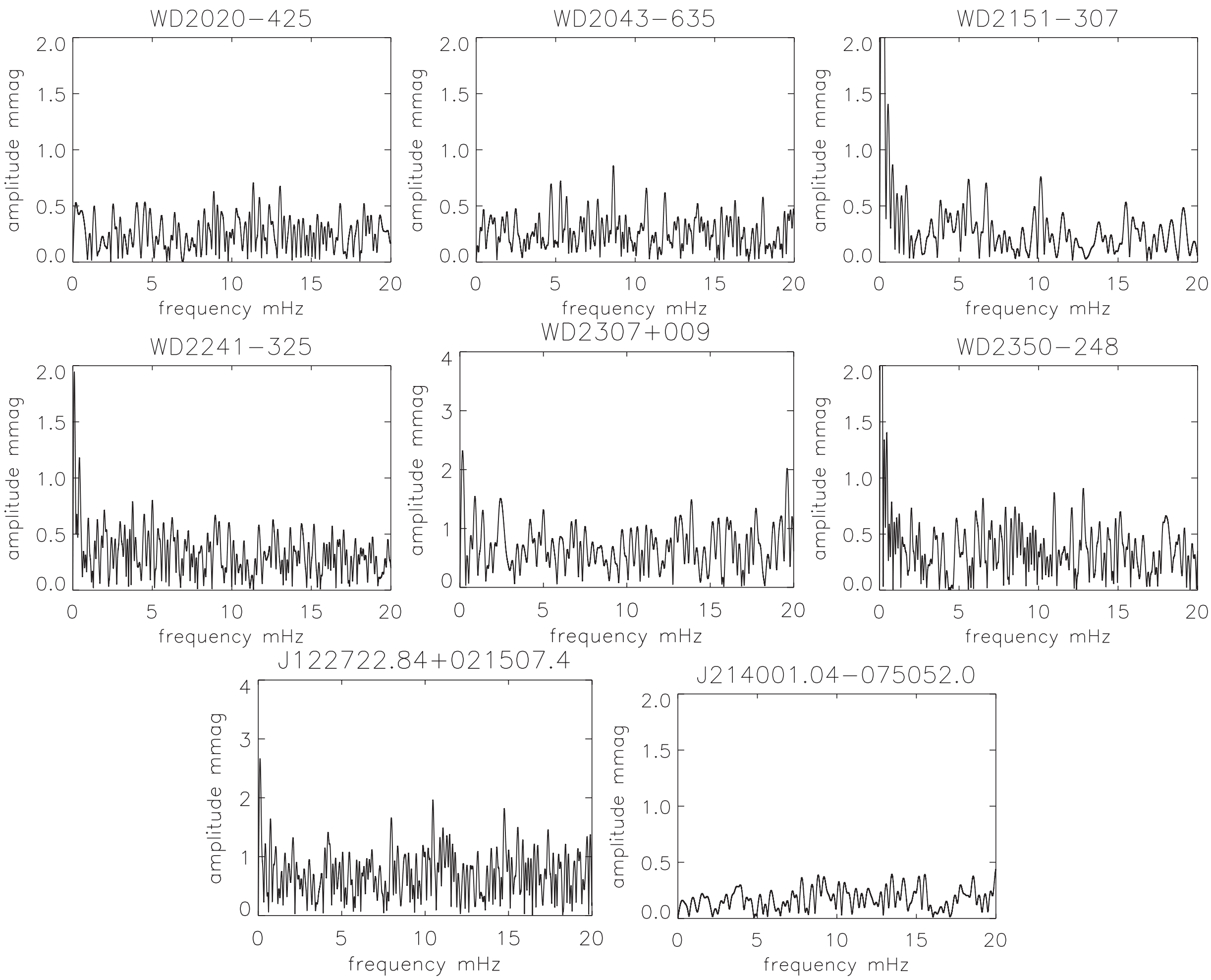

Figure 2 – *continued*

pulsators with amplitudes below our current detection limits. This supposition can be tested with longer runs and larger telescopes, giving lower photometric noise levels.

4 DISCUSSION

We selected WD1017−138 as a target to test for pulsation because of its published characteristics (Finley et al. 1997; Marsh et al. 1997; Napiwotzki, Green & Saffer 1999). It has a hydrogen atmosphere, an effective temperature of $T_{\rm eff}$ = 31500 K, a surface gravity of $\log g = 7.9$ (cgs) and a mass of 0.58 $M_\odot$. All of these indicate that WD1017−138 is a typical white dwarf star at the cool end of the 45 000–30 000 K temperature range where Shibahashi (2005) predicted the existence of this new class of pulsators. WD1017−138 has also been used as a background source to study the interstellar medium with Far Ultraviolet Spectroscopic Explorer (FUSE) UV spectra (Lehner et al. 2003) with no indication of any metal lines in its spectrum. Thus, there appears to be nothing unusual or special about it.

Because of the importance of this conclusion, we have tested it further by modelling three 5-min exposure, high-resolution spectra obtained with the Ultraviolet and Visual Echelle Spectrograph (UVES) on the Very Large Telescope (VLT) from the ESO science archive with synthetic spectra computed with TLUSTY and SYNSPEC (Lanz & Hubeny 1995). Fig. 3 shows our model fits to some of the hydrogen lines, giving $T_{\rm eff}$ = 32 600 K, $\log g = 7.8$ (cgs) and M = 0.55 $M_\odot$, values similar to those of previous studies. Also, there is no indication in the UVES spectra of any helium or metal lines. We therefore confidently conclude that WD1017−138 is a pulsat-

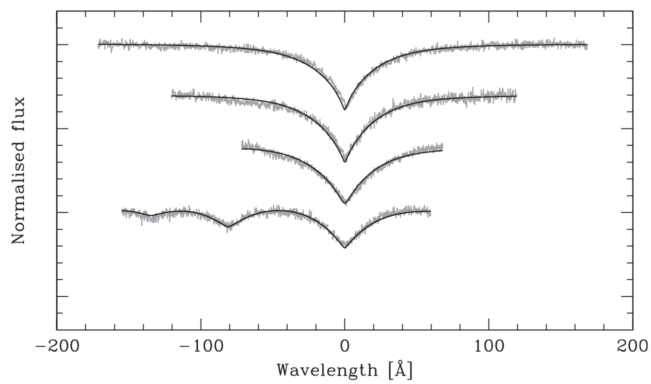

Figure 3. High-resolution spectra of WD1017−138 taken with the UVES spectrograph on the VLT. White dwarf models fitted to the Balmer lines of hydrogen (Hβ, Hγ, Hδ and H8 and H9, from top to bottom) give $T_{\rm eff}$ = 32600 K, $\log g = 7.8$ (cgs) for an inferred mass of 0.55 $M_\odot$, in good agreement with other determinations. The spectra also show that WD1017−138 is a DA hydrogen atmosphere white dwarf with no trace of helium in its spectrum.

ing hot DAV white dwarf with a typical hydrogen atmosphere at the cool end of the 45 000–30 000 K temperature range. The clarity and consistency of the pulsation signals on the two nights give us confidence that the two previous examples (Kurtz et al. 2008) are also real; hence, we conclude that there is a probable new class of pulsating white dwarf stars at the cool edge of the 45 000–30 000 K temperature range, which we call the hot DAV stars.

The hot DAV stars we have discovered have hydrogen atmospheres and effective temperatures somewhat hotter than the DBV helium atmosphere V777 Her stars. Our understanding of the deficit of helium atmosphere white dwarfs in the evolutionary cooling sequence between 45 000 and 30 000 K requires the hot DAV stars to have a very thin layer of hydrogen on top of a much thicker layer of helium (Fontaine & Wesemael 1987; Shibahashi 2005). The hydrogen surface layer is subadiabatic, hence damps the oscillation. In our models, as the hydrogen layer becomes thicker, the growth rate decreases, and eventually the pulsation is stabilized. Thus, our discovery of pulsation in the hot DAV stars strongly supports the thin hydrogen layer model for these stars.

Having established this probable new class of pulsating white dwarfs, the hot DAV stars, where do we go from here? The importance of these stars lies in the potential to measure directly the atmospheric layer thickness of the hydrogen layer. This is feasible, as is shown by the successful determination of the important He layer thickness in V777 Her itself, the prototype of the DBV pulsating stars. This star has $T_{\rm eff} = 25\,900$ K and $\log g = 7.9$ (cgs) with no atmospheric hydrogen. It is one of the most intensively observed and modelled of all the pulsating white dwarfs (Winget et al. 1994; Vuille et al. 2000; Provencal et al. 2009). From the deviation of the g-mode periods from the nearly equal spacing expected for a uniform chemical composition atmosphere, Winget et al. (1994) derived an atmospheric helium layer mass of $M_{\rm He} = (2.0 \pm 1.0) \times 10^{-6}\, M_{\rm star}$, where $M_{\rm star} = 0.63 \pm 0.03$ $\mathrm{M}_{\odot}$ was derived from modelling the spacing of the dipole pulsation modes.

Our goal is a similar analysis of a hot DAV star, but while V777 Her has pulsation modes with amplitudes of up to 170 mmag, WD1017−138 so far has only a single mode with amplitude 1 mmag, and we only found upper limits of 0.5–3 mmag in 22 other stars of similar temperature in the 45 000–30 000 K temperature range with our NTT run and for 8 other stars in our previous work (Kurtz et al. 2008). Thus, these stars appear to have relatively low observed amplitudes. This is not surprising, given that our stability analysis shows that higher degree modes are expected, and those are less easily detected. This means that asteroseismic inference is limited for these stars until much higher precision can be obtained from space, or until higher amplitude examples can be discovered. We predict that with an improvement in precision of 10–100 times, as is currently possible with the *Kepler* mission, many of these stars could be detected with rich frequency spectra. However, there are currently no white dwarfs in the required temperature range known in the *Kepler* field of view.

Further searches for hot DAVs from the ground are worthwhile, since higher amplitude pulsators remain a possibility. As an example, until recently there were only nine known DBV stars. That number has now been doubled (Nitta et al. 2009), yet V777 Her itself continues to be the best case. The other DBV stars have lower amplitudes, often much lower. Similarly, it is possible that there exist high-amplitude hot DAV stars. We have found 5 stars in our previous study (Kurtz et al. 2008) and 21 stars in this study with no detectable pulsations at the level of 0.5–3 mmag. But with many more white dwarfs now known, larger amplitude pulsators may be found in the larger sample.

Thus, there is potential that our newly discovered class of hot DAV pulsating white dwarf stars will ultimately provide a quantitative test of the theory of the deficit of helium atmosphere white dwarfs in the 45 000–30 000 K temperature range, measure the hydrogen layer thickness in these stars, and determine observationally and quantitatively the amount of residual hydrogen in their atmospheres. This is important for our understanding of the evolution of the white dwarfs themselves, for the late stages of red giant evolution and for the mass-loss processes that produce planetary nebulae. Finding a large-amplitude hot DAV equivalent to V777 Her will open a new realm of asteroseismology.

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